Chapter 5
Zooplankton and Mysid Shrimp

Introduction

Mysid shrimp and zooplankton are important food organisms for larval, juvenile, and small fish, such as delta smelt, juvenile salmon, striped bass, and small splittail. The Neomysis/Zooplankton Study seeks to determine the annual population level of *Neomysis mercedis*, other mysids, and various zooplankton species or genera to assess the size of the food resource for fish. The study also seeks to detect the presence of exotic species recently introduced to the estuary, to monitor the distribution and abundance of these exotics, and to determine their impacts on native species. The study began to monitor *N. mercedis* in June 1968 and was expanded in January 1972 to include copepods, cladocera, and rotifers. *Acanthomysis bowmani* was distinguished and enumerated in 1994. Identification and counting of the other five mysid species (*A. aspera*, *A. hwanhaiensis*, *A. macropsis*, *Deltamysis holmquistae*, and *N. kadiakensis*) began in 1998.

Methods

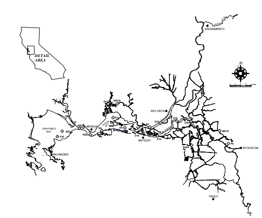

Figure 5-1 Zooplankton monitoring stations

Macro-, meso-, and micro-zooplankton were sampled monthly at 15 to 20 stations in the Delta and Suisun Bay (Figure 5-1). Eighteen of these stations were at fixed geographic locations. Two stations were located or "floated" to locations where bottom electrical conductance was 2 and 6 mS/cm, respectively. One fixed station in San Pablo Bay and two fixed stations in Carquinez Strait were sampled only when their surface salinity was less than 20 mS/cm.

At each station three types of gear were deployed: a *Neomysis* net, 1.48 m long and 29 cm in mouth diameter, mesh size 0.505 mm, mounted on a towing frame made of steel tubing, with a General Oceanics net meter at its mouth; a Clarke-Bumpus net for zooplankton, mouth diameter 12.5 cm and mesh size 154 µm that was mounted above the *Neomysis* net on the same frame; and a 15-liter/minute-capacity pump. At each station, while underway, the towing frame was lowered to the bottom and retrieved obliquely in several steps over a 10-minute period. Zooplankton small enough to pass through the Clarke-Bumpus net (mostly copepod nauplii, rotifers, and Oithonids) were sampled with the pump. At each station, the pump intake was lowered to the bottom, raised slowly to the surface, and then lowered and raised a second time. The pumped water was discharged into a 19-liter carboy, which was shaken, and a 1.5 to 1.9 liter sample was decanted into a jug. All samples were preserved in buffered 10% formalin and returned to the laboratory for identification. The Department of Water Resources (DWR) provided temperature (to 0.1 ^{o}C) and specific conductance (µS/cm) measurements taken from the top (1 meter from surface) and bottom (1 meter from bottom) of the water column at each station at high water slack using a Seabird submersible sampler and recorded with a Seabird CTD 911+ data logger.

A zooplankton taxon's distribution within the estuary is determined by its salinity requirement rather than geography. Therefore, to calculate monthly abundance indices, the sample area was divided into the following three zones based on bottom specific conductance: (1) the entrapment zone (1.8 mS/cm to 6.6 mS/cm); (2) upstream from the entrapment zone (< 1.8 mS/cm); and (3) downstream from the entrapment zone (> 6.6 mS/cm). The density for each taxon was calculated as the number of organisms/m^3 for each station and type of gear. Monthly abundance was calculated as the mean monthly density of each taxon in each zone. The number of stations in each zone varied month to month based on upstream and downstream shifts in the salinity gradient. Although none of the species were present at all stations in every month, averaging the density by the total number of stations sampled in each zone provided a common and consistent base for comparing taxon densities.

Abundance data were log transformed (log10(abundance+1)) before plotting to improve interpretation by reducing month-to-month variability.

For brevity, the meso- and micro-zooplankton were divided into the following four groups: calanoid copepods, cyclopoid copepods, cladocera and rotifers. The taxa in each group were ranked by mean annual abundance and the monthly abundances of the three or four most abundant taxa in each group were presented in this report.

Results

The year 2003 saw changes in the relative abundance of mysids in the upper estuary. *Acanthomysis bowmani* and *Neomysis kadiakensis* remained the dominant mysids in the upper estuary but a native high salinity mysid, *Alienacanthomysis macropsis*, replaced *Neomysis mercedis* as the third most abundant species. The introduced *Acanthomysis hwanhaiensis*, the fourth most abundant mysid in 2001 and 2002, declined to fifth most abundant. Nearly all of the meso- and micro-zooplankton retained their respective abundance ranks from 2001 and 2002.

Mysids

Acanthomysis bowmani (mean abundance = 6.419 m^{-3}) was the most abundant mysid in all areas in 2003 (Figure 5-2). *Acanthomysis bowmani* abundance was highest in the entrapment zone and downstream from the entrapment zone. Peak *A. bowmani* abundance occurred from April through September except downstream from the entrapment zone where the peak abundance period lasted from May through August.

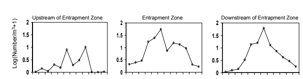

Figure 5-2 Monthly *Acanthomysis bowmani* abundance upstream, in, and downstream of the entrapment zone for 2003

Neomysis kadiakensis (mean abundance = 0.348 m^{-3}), the second most abundant mysid, was found primarily downstream from the entrapment zone, with a few found within and none found upstream from the entrapment zone (Figure 5-3). In the entrapment zone the highest abundance occurred in January. There was a second peak in May that coincided with the highest abundance value downstream from the entrapment zone. Downstream from the entrapment zone, peak abundance occurred in April through August. *Neomysis kadiakensis* abundance has been steadily increasing in the upper

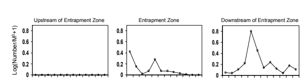

Figure 5-3 Monthly *Neomysis kadiakensis* abundance upstream, in, and downstream of the entrapment zone for 2003

estuary since 1998. In 1998 *N. kadiakensis* was the fourth most abundant mysid overall. In 1999 it was the third most abundant. Since 2001 it has been the second most abundant mysid in the upper estuary.

Alienacanthomysis macropsis (mean abundance =0.036 m^{-3}), a native mysid that is normally found in high salinity water, was the third most abundant mysid. In 2003 it was taken only downstream from the entrapment zone (Figure 5-4). *A. macropsis* abundance peaked in January and declined to zero by June. Only a few *A. macropsis* were caught in November.

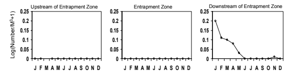

Figure 5-4 Monthly *Aliencanthomysis macropsis* abundance upstream, in, and downstream of the entrapment zone for 2003

Neomysis mercedis (mean abundance = 0.015 m^{-3}), the fourth most abundant mysid, was caught primarily upstream, as well as inside, of the entrapment zone. Peak *N. mercedis* abundance occurred in May and June (Figure 5-5). Although the abundance of *N. mercedis* has been steadily declining since the introduction of *Potamocorbula amurensis* in 1989, its abundance increased slightly from 2002. *Neomysis mercedis* was taken in only May and June upstream from and in the entrapment zone and only in July downstream from the entrapment zone.

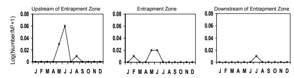

Figure 5-5 Monthly *Neomysis mercedis* abundance upstream, in, and downstream of the entrapment zone for 2003

Calanoid Copepods

The native *Acartia* spp. (mean abundance = 460.755 m^{-3}) was the most abundant calanoid copepod in the upper estuary. It occurred primarily downstream from the entrapment zone (Figure 5-6). The period of peak abundance in and downstream from the entrapment zone was from January through May. Upstream from the entrapment zone, *Acartia* was taken only from January through April.

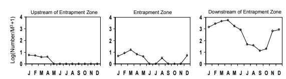

Figure 5-6 Monthly *Acartia* spp abundance upstream, in, and downstream of the entrapment zone for 2003

The introduced *Pseudodiaptomus forbesi* (mean abundance = 413.638 m^{-3}) was the second most abundant calanoid copepod in the upper estuary 2003 (Figure 5-7). *P. forbesi* abundance was greatest upstream from the entrapment zone and almost as high in the entrapment zone. Peak *P. forbesi* abundance upstream from and in the entrapment zone was from June through November. Downstream from the entrapment zone the peak abundance was from July through November.

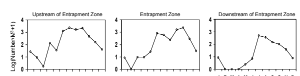

Figure 5-7 Monthly *Pseudodiaptomus forbesi* abundance upstream, in, and downstream of the entrapment zone for 2003

The third most abundant calanoid copepod was the introduced *Acartiella sinensis* (mean abundance = 155.022 m^{-3}) (Figure 5-8). The highest abundances of this copepod were found in and downstream from the entrapment zone, although large numbers were also found upstream from the entrapment zone. The lowest abundances occurred in May and June with peak abundances occurring from July through December.

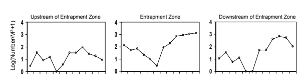

Figure 5-8 Monthly *Acartiella sinensis* abundance upstream, in, and downstream of the entrapment zone for 2003

Sinocalanus doerrii, (mean abundance = 135.109 m^{-3}), another introduced species, was the fourth most abundant calanoid copepod (Figure 5-9). *S. doerrii* abundance reached high levels upstream from and in the entrapment zone. The peak abundance was from April through June upstream from and in the entrapment zone and in March and April downstream from the entrapment zone.

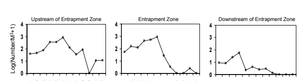

Figure 5-9 Monthly *Sinocalanus doerrii* abundance upstream, in, and downstream of the entrapment zone for 2003

Cyclopoid Copepods

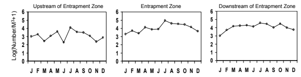

Figure 5-10 Monthly *Limnoithona tetraspina* abundance upstream, in, and downstream of the entrapment zone for 2003

Limnoithona tetraspina (mean abundance = 10,844.630 m^{-3}), has been the most abundant cyclopoid copepod since its introduction in 1994 (Figure 5-10). *Limnoithona tetraspina* was abundant in all three zones, but was most abundant in and downstream from the entrapment zone. In all three zones the highest abundance was in July. Upstream from the entrapment zone, the period of peak abundance was from July through September. In the entrapment zone, peak abundance ran from July through November and, downstream from the entrapment zone, peak abundance occurred from March through August.

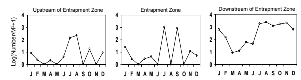

Figure 5-11 Monthly *Oithona davisae* abundance upstream, in, and downstream of the entrapment zone for 2003

The introduced *Oithona davisae* (mean abundance = 426.288 m^{-3}) was the second most abundant cyclopoid copepod and occurred primarily downstream from the entrapment zone (Figure 5-11). *Oithona davisae* was also abundant in the other two areas but its occurrence there was erratic during the last half of the year. Upstream from the entrapment zone, the peak period was in July and August. In the entrapment zone there were two peaks; one in July and the other in September. Downstream from the entrapment zone, peak abundance was from July through December.

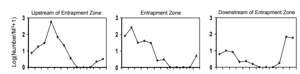

Figure 5-12 Monthly *Acanthocyclops vernalis* abundance upstream, in, and downstream of the entrapment zone for 2003

The native *Acanthocyclops vernalis* (mean abundance = 43.142 m^{-3}) was the third most abundant cyclopoid copepod and was abundant throughout the sampling area, but declined from upstream from the entrapment zone to downstream (Figure 5-12). Its peak abundance period appeared earlier with each successive downstream area. Upstream from the entrapment zone, the peak abundance period was from February through June. In the entrapment zone, the peak abundance period began in January and ended in May. Downstream from the entrapment zone, there was a peak period from January through March and another one in November and December.

Cladocera

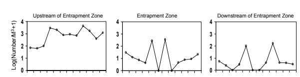

Figure 5-13 Monthly *Bosmina* spp abundance upstream, in, and downstream of the entrapment zone for 2003

Bosmina longirostris (mean abundance = 561.350 m^{-3}) was the most abundant cladoceran in the upper estuary in 2003 (Figure 5-13). It was abundant throughout the year upstream from the entrapment zone with peak abundances from April through October. In the entrapment zone, *B. longirostris* had two spikes, one in May and one in July, followed by an abundance estimate of zero. Downstream from the entrapment zone, abundance also showed two spikes: one in May and one in September.

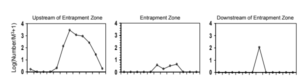

Figure 5-14 Monthly *Diaphanosoma* spp abundance upstream, in, and downstream of the entrapment zone for 2003

Diaphanosoma spp. (mean abundance = 195.120 m^{-3}), the second most abundant cladoceran for 2003, was taken almost exclusively upstream from the entrapment zone (Figure 5-14). It was the third most abundant cladoceran in 2001 and 2002. Peak abundance for this genus occurred from June through November upstream from the entrapment zone. The 2003 abundance peaks followed the typical pattern. In the entrapment zone *Diaphanosoma* was caught in low numbers from June through September. *Diaphanosoma* occurred downstream from the entrapment zone only in July during 2003.

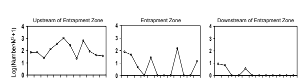

Figure 5-15 Monthly *Daphnia* spp abundance upstream, in, and downstream of the entrapment zone for 2003

Although it was the second most abundant cladoceran in 2002, *Daphnia* spp. (mean abundance = 119.355) was the least abundant of the identified cladocera for 2003 (Figure 5-15). It was most abundant upstream from the entrapment zone where its peak abundance occurred from April through July with a spike in September. *Daphnia* was present from January through March, and then occasionally appeared in relatively large numbers throughout the rest of the year. *Daphnia* was absent downstream from the entrapment zone for most of the year, appearing only in January, February, and May.

Rotifers

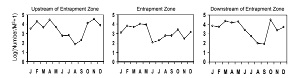

Figure 5-16 Monthly *Synchaeta* spp abundance upstream, in, and downstream of the entrapment zone for 2003

The genus *Synchaeta* (excluding *Synchaeta bicornis*) (mean abundance = 8,437.141 m^{-3}) was the most abundant rotifer taxon (Figure 5-16). The typical peak abundance period for *Synchaeta* begins in October and continues through May or June of the following year. This pattern was evident in all areas during 2003.

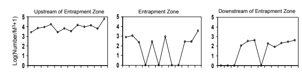

Figure 5-17 Monthly *Polyarthra* spp abundance upstream, in, and downstream of the entrapment zone for 2003

The genus *Polyarthra* (mean abundance = 5,491.975 m^{-3}) was the second most abundant rotifer (Figure 5-17). It was most abundant upstream from the entrapment zone and least abundant downstream from the entrapment zone. Upstream from the entrapment zone *Polyarthra* abundance remained fairly uniform throughout 2003. Inside the entrapment zone, *Polyarthra* was abundant from January through March, but very erratic throughout the rest of the year. *Polyarthra* was not taken downstream from the entrapment zone until April. Beginning in April, *Polyarthra* was moderately abundant and its abundance was stable for the rest of the year except for July when it was absent.

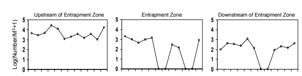

Figure 5-18 Monthly *Keratella* spp abundance upstream, in, and downstream of the entrapment zone for 2003

The third most abundant rotifer taxon was the genus *Keratella* (mean abundance = 3,372.417 m^{-3}) (Figure 5-18). The highest *Keratella* abundance occurred upstream from the entrapment zone, where its abundance was relatively stable throughout 2003. Inside the entrapment zone, *Keratella* abundance was fairly stable until June when it disappeared from the catch for a couple of months. A similar disappearance occurred in October and November. For the last six months of 2003, abundance was slightly lower. Downstream from the entrapment zone, *Keratella* abundance was stable except for a brief absence during July and August.

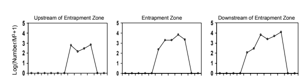

Figure 5-19 Monthly *Synchaeta bicornis* abundance upstream, in, and downstream of the entrapment zone for 2003

The fourth most abundant rotifer taxon was *Synchaeta bicornis* (mean abundance = 1,341.415 m^{-3}) (Figure 5-19). It is a small rotifer that shows wide abundance swings both inter- and intra-annually. This species was most abundant downstream from the entrapment zone and least abundant upstream from the entrapment zone. In the entrapment zone and downstream from it, this rotifer's abundance steadily rose until it dropped to zero in November. It was not caught in any area during winter or late fall.

Summary

The monthly abundance patterns were typical of those for recent years. *Acanthomysis bowmani* and *Neomysis kadiakensis* remained the two most abundant mysids. *Neomysis mercedis* dropped to fourth most abundant after *Alienacanthomysis macropsis*. The abundance ranks of the meso- and micro-zooplankton were essentially the same as for 2002.

Figure 5-1 Zooplankton monitoring stations

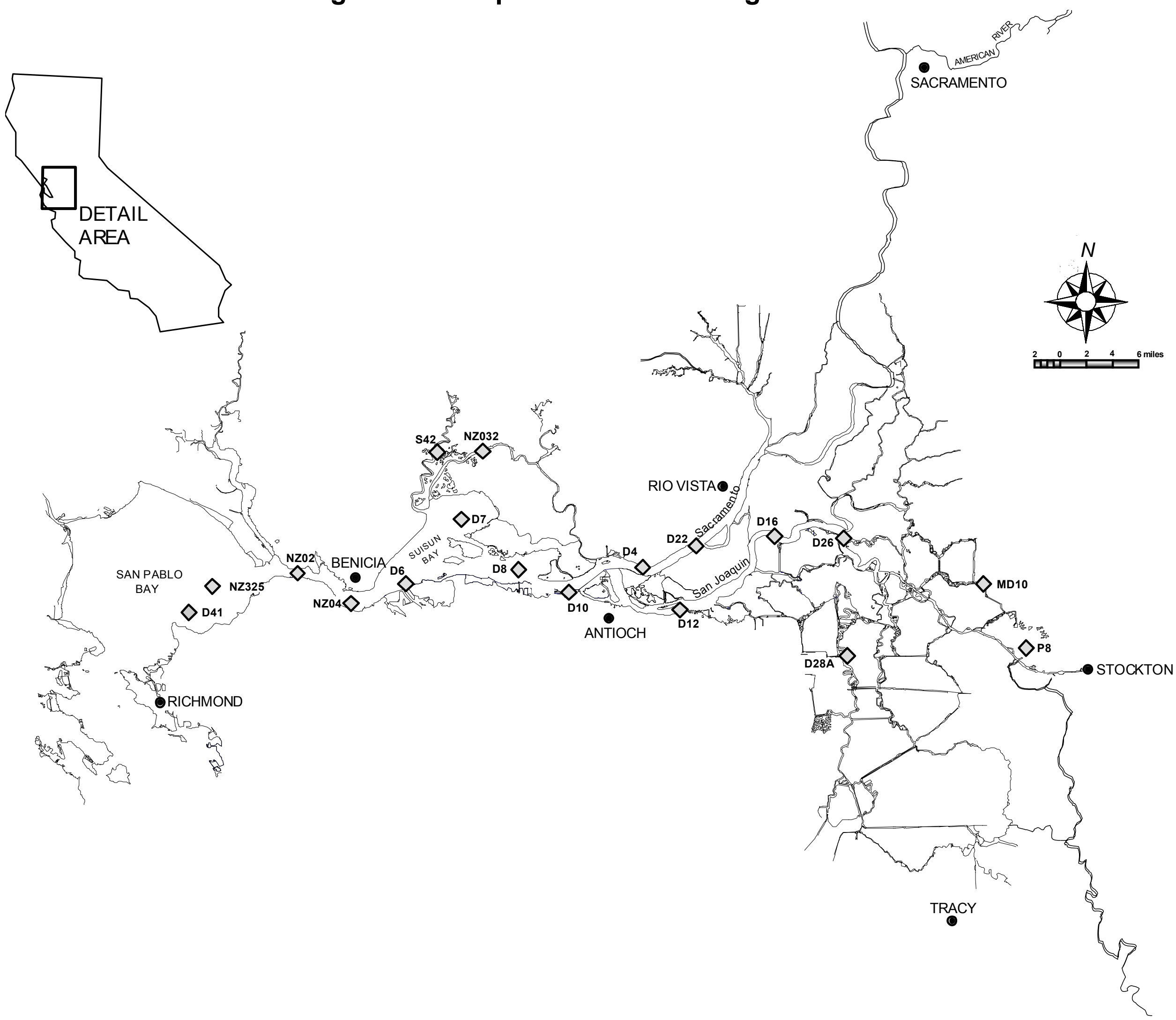

Figure 5-2 Monthly *Acanthomysis bowmani* abundance upstream, in, and downstream of the entrapment zone for 2003

Figure 5-3 Monthly *Neomysis kadiakensis* abundance upstream, in, and downstream of the entrapment zone for 2003

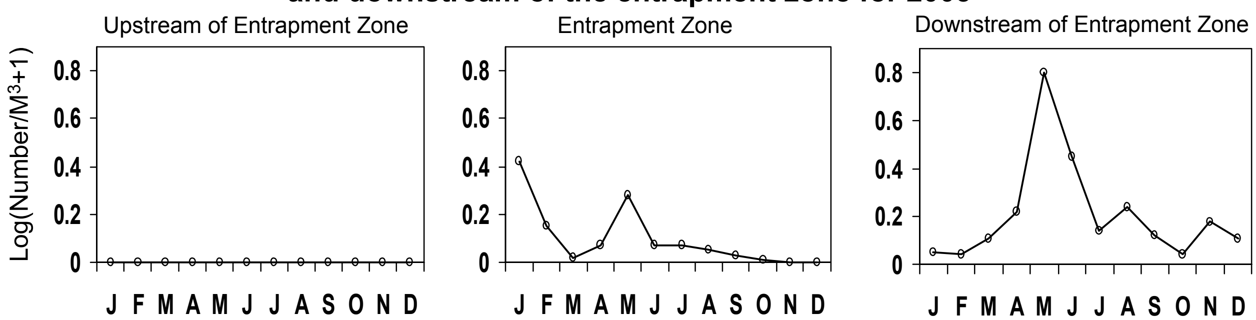

Figure 5-4 Monthly *Aliencanthomysis macropsis* abundance upstream, in, and downstream of the entrapment zone for 2003

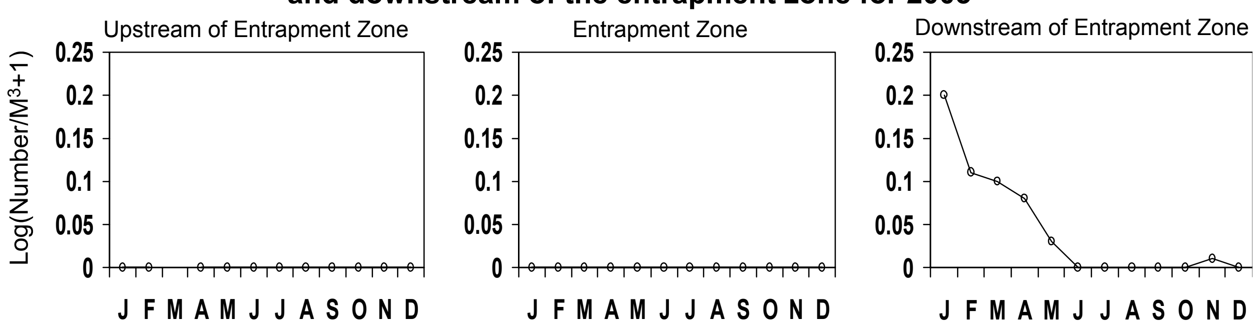

Figure 5-5 Monthly *Neomysis mercedis* abundance upstream, in, and downstream of the entrapment zone for 2003

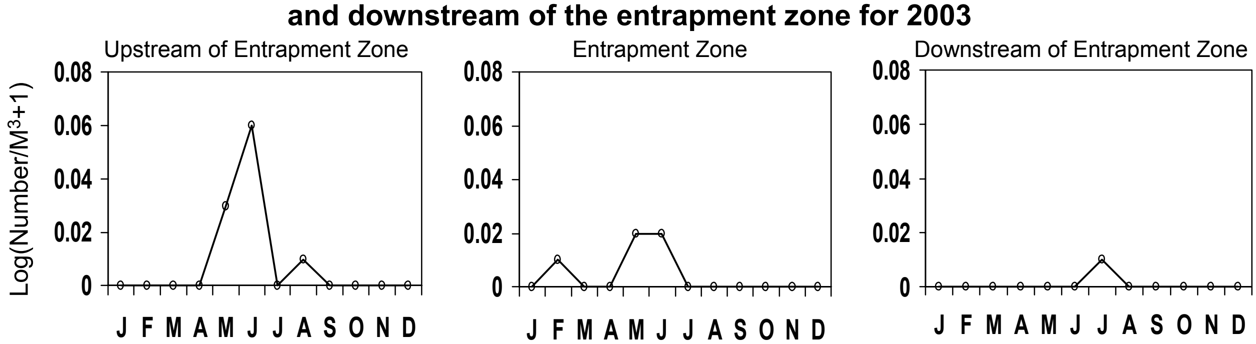

Figure 5-6 Monthly *Acartia* spp. abundance upstream, in, and downstream of the entrapment zone for 2003

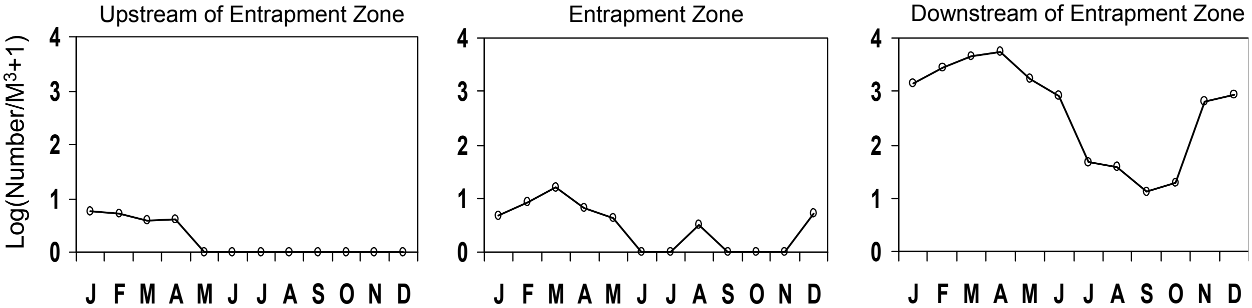

Figure 5-7 Monthly *Pseudodiaptomus forbesi* abundance upstream, in, and downstream of the entrapment zone for 2003

Figure 5-8 Monthly *Acartiella sinensis* abundance upstream, in, and downstream of the entrapment zone for 2003

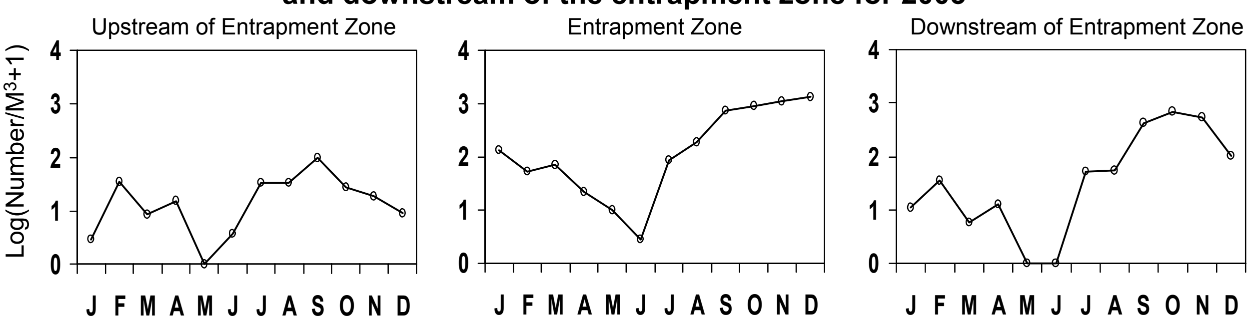

Figure 5-9 Monthly *Sinocalanus doerrii* abundance upstream, in, and downstream of the entrapment zone for 2003

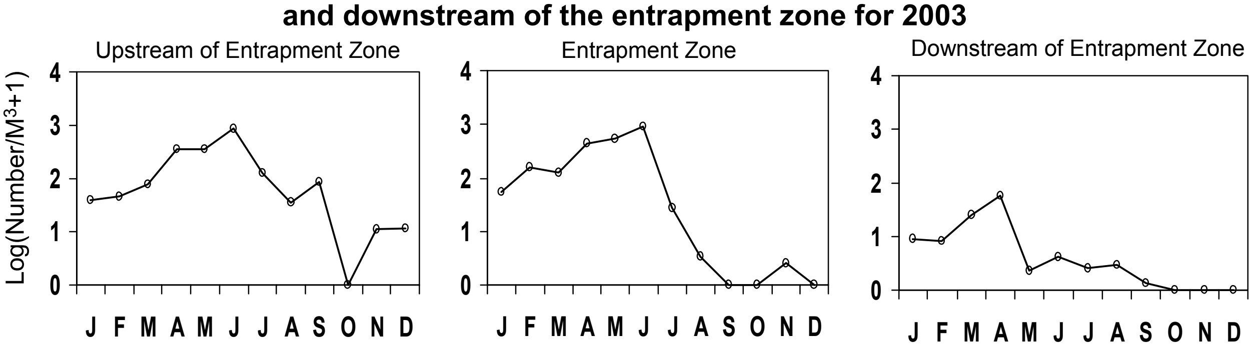

Figure 5-10 Monthly *Limnoithona tetraspina* abundance upstream, in, and downstream of the entrapment zone for 2003

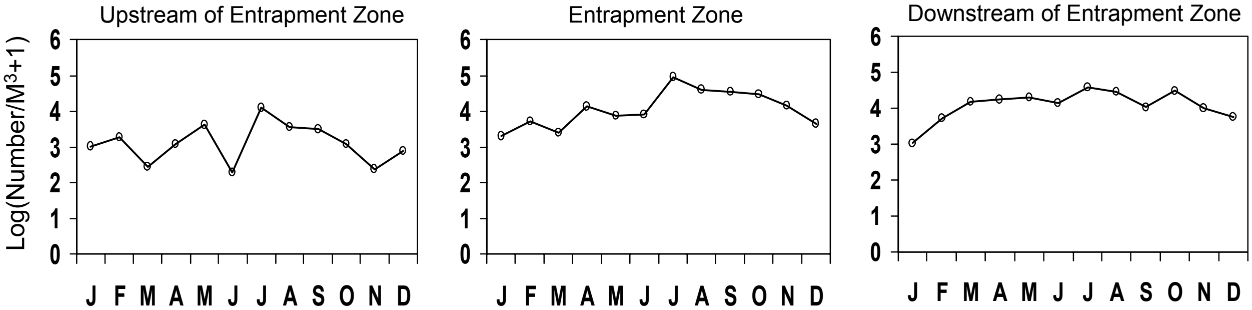

Figure 5-11 Monthly *Oithona davisae* abundance upstream, in, and downstream of the entrapment zone for 2003

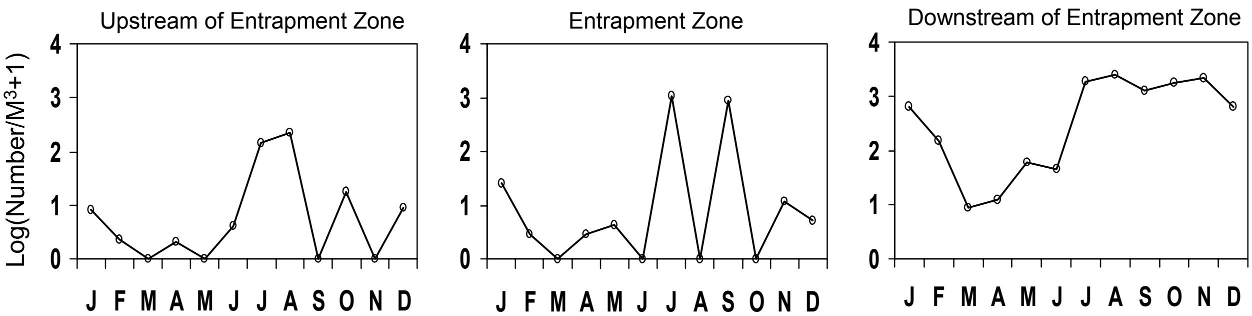

Figure 5-12 Monthly *Acanthocyclops vernalis* abundance upstream, in, and downstream of the entrapment zone for 2003

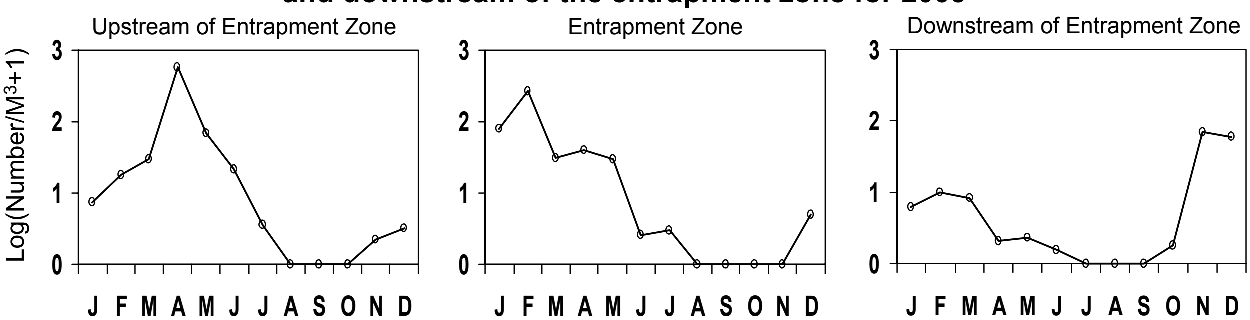

Figure 5-13 Monthly *Bosmina* spp. abundance upstream, in, and downstream of the entrapment zone for 2003

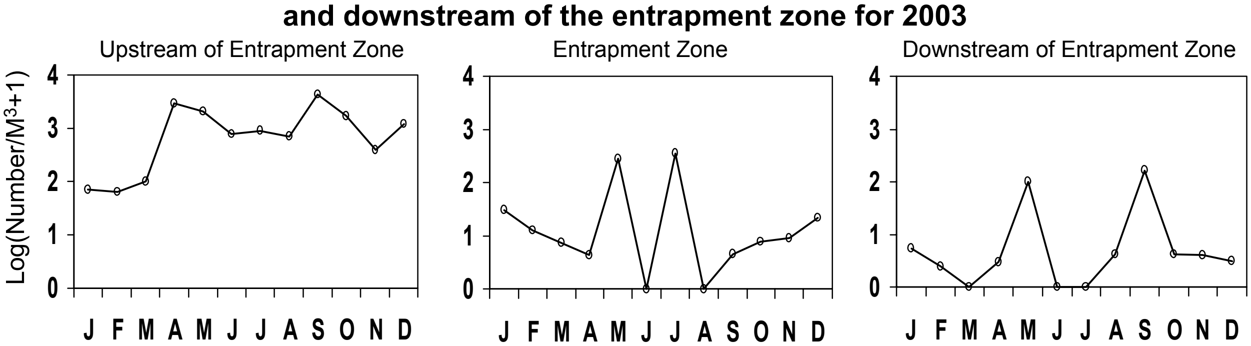

Figure 5-14 Monthly *Diaphanosoma* spp. abundance upstream, in, and downstream of the entrapment zone for 2003

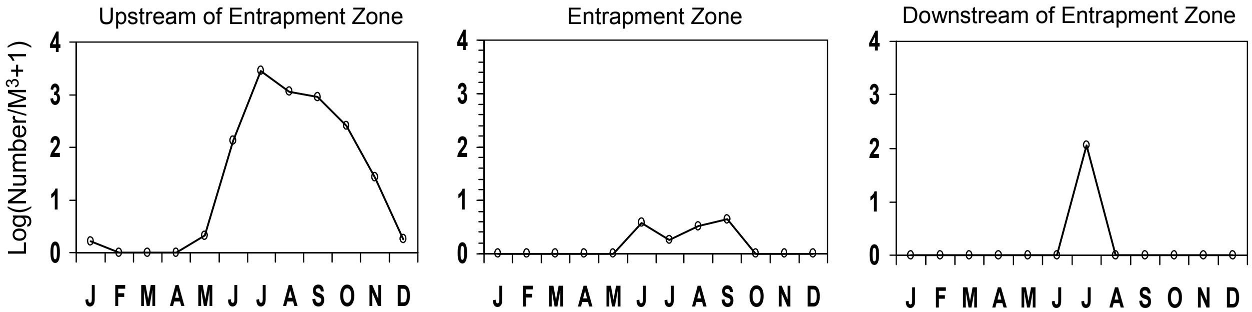

Figure 5-15 Monthly *Daphnia* spp. abundance upstream, in, and downstream of the entrapment zone for 2003

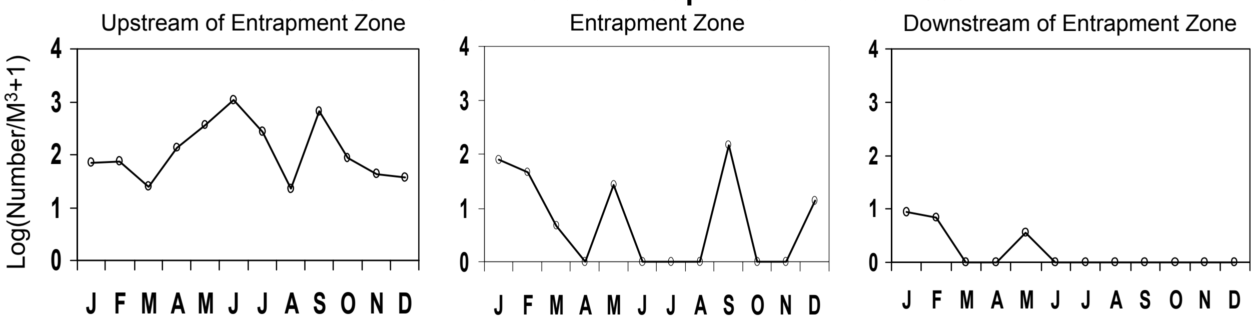

Figure 5-16 Monthly *Synchaeta* spp. abundance upstream, in, and downstream of the entrapment zone for 2003

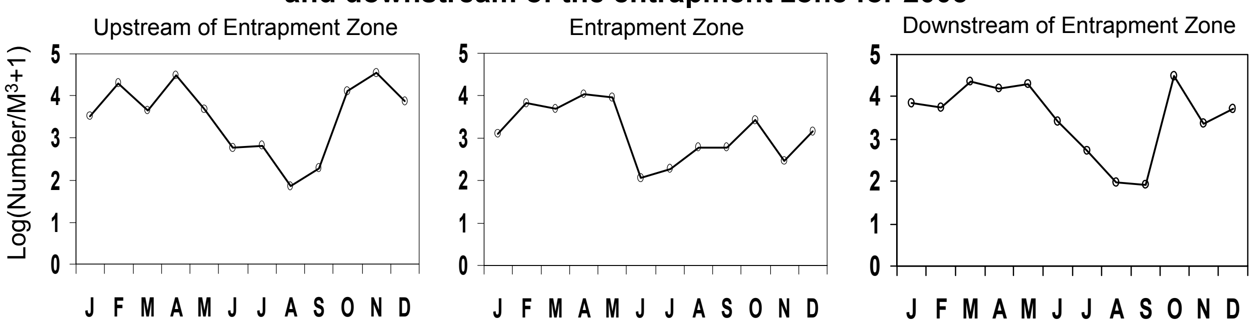

Figure 5-17 Monthly *Polyarthra* spp. abundance upstream, in, and downstream of the entrapment zone for 2003

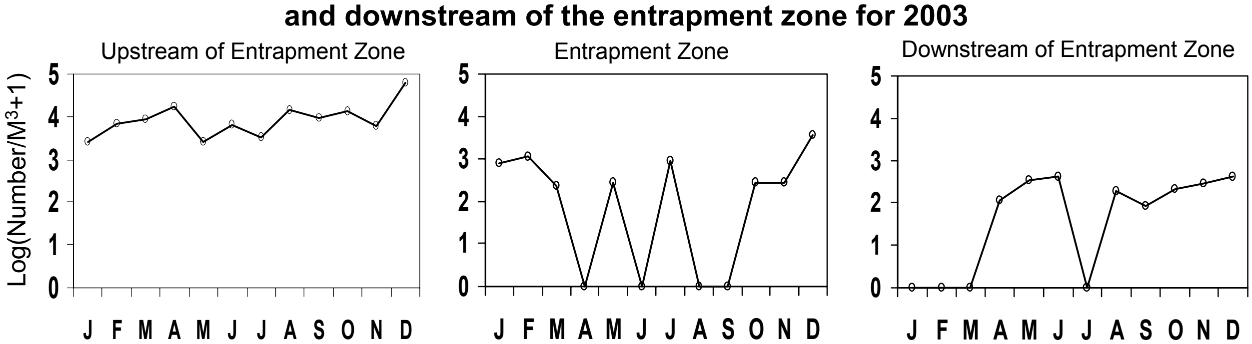

Figure 5-18 Monthly *Keratella* spp. abundance upstream, in, and downstream of the entrapment zone for 2003

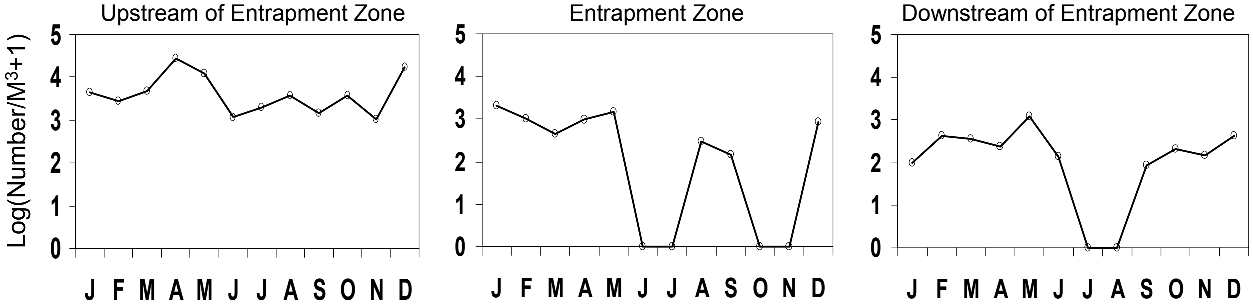

Figure 5-19 Monthly *Synchaeta bicornis* abundance upstream, in, and downstream of the entrapment zone for 2003